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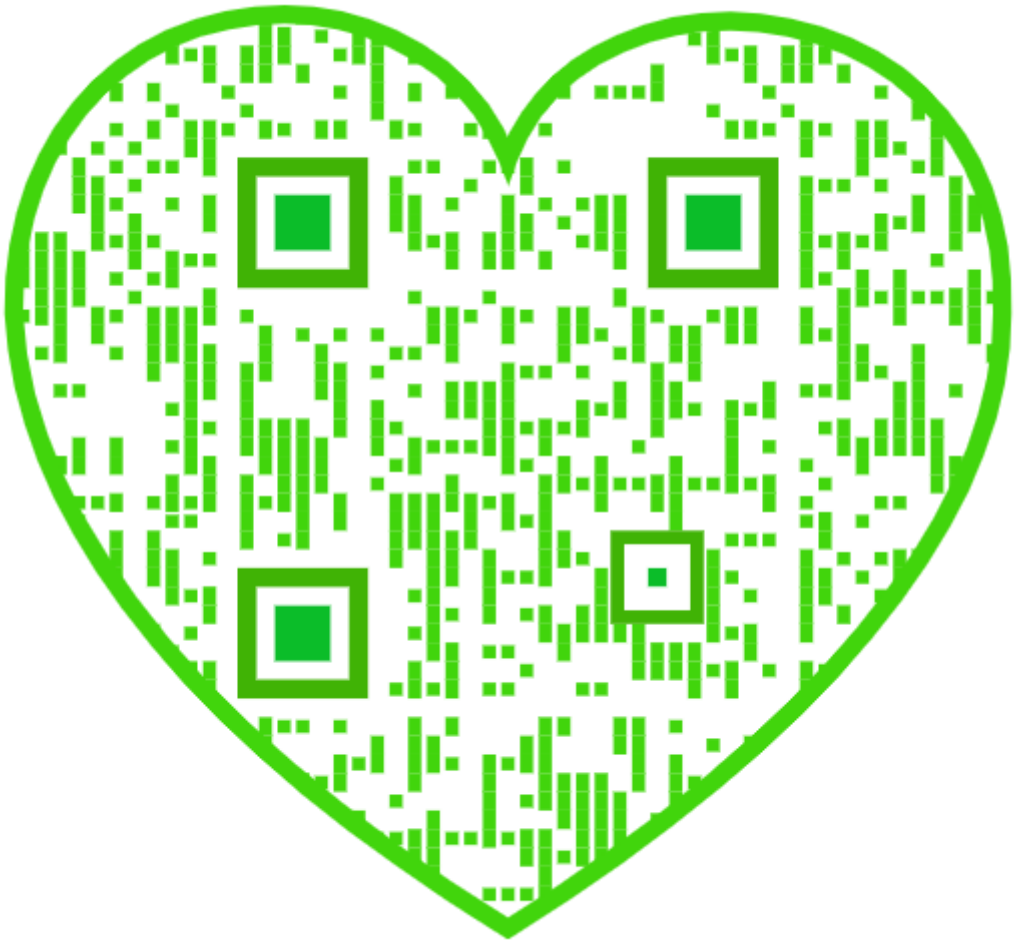

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APIARY EXPERIMENTS.

—BY—

CLARENCE P. GILLETTE.

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APIARY EXPERIMENTS.

FOUNDATION IN COMB BUILDING.

By CLARENCE P. GILLETTE.

Honey bees collect liquid sweets from all available sources, chiefly in the form of nectar from flowers, and when the product has been elaborated in the honey-stomach and afterwards stored in comb, we call it honey.

The material from which the comb is built is not collected as wax, but is formed within the body and secreted in the form of thin scales between the abdominal segments on the under side.

As the wax is elaborated within the body, the bee must be supplied with food out of which to form it and, according to experiments reported on another page, it requires about one pound of wax for every twenty-five pounds of honey stored in comb. The food required for the secretion of wax is, for the most part, honey; and as it requires several pounds of corn to produce one pound of beef or butter, so it doubtless requires several pounds of honey as food for worker bees to enable them to produce one pound of wax.

But the consumption of honey for wax production does not represent the total cost of the wax to the colony. The bees that secrete it are called off from the field force, so that the income of the colony is lessened. In a state of nature this wax production entails no heavy drain upon the the colony, as the comb, once built, lasts for years; but where comb honey is being produced for the market, it becomes a matter of economic importance to know to what extent and in what form wax can best be furnished bees for their use in comb building.

So far as we know at present, there is but one general way to furnish the wax for this use, and that is in some form of artificial comb foundation. But their are many types of this foundation. Is it better to have the base or midrib only—the "no wall" foundation? or is it better to have the cell walls outlined for the bees? If the latter, should we have these walls short or long? In either case, is

it better to put most of the wax in the midrib or the cell walls? When it is determined how the wax is best proportioned between the midrib and cell walls, what weight of foundation is best?

The experiments here reported were undertaken for the purpose of casting some light upon these and related problems and, it is believed, with some good results. It is not to be expected that all these questions are fully settled in this paper.

DO BEES USE WAX FROM ARTIFICIAL FOUNDATIONS TO EXTEND THE CELL WALLS AND THE COMB MIDRIB?

The common belief that wax is so used was graphically proven by the following experiment:

A few sheets of thin foundation that was made black by the addition of lamp black to the melted wax were prepared for me by Mr. C. B. Elliott, of Denver. This foundation was used in sections which were placed in supers for comb honey. In some sections starters one inch wide were used, while in others were placed full sheets. The bees accepted this black foundation as readily as any and built comb upon it. A photograph of comb built upon this foundation is shown in Plate 1. At *a* is a section containing a starter one inch wide that the bees had worked but little. At *b* are two cross sections of comb built upon such a starter. The white cross-lines show where the lower edges of the starters came, and the dark color shows to what extent the foundation was used in extending the comb. At *c* is a section of drawn comb built upon a short starter as shown at *a*. The white line marks the lower margin of the foundation, and the dark color in the comb shows to what extent the foundation was used in building down the comb. At *d* is shown comb built on a large piece of the black foundation. The cell walls are deep black at the bottom and gradually fade until the top or outer end of the wall is reached, where the dark color hardly shows. This could only come about by the bees using other wax, probably directly from their bodies, which was mixed with the wax of the foundation.

These experiments prove so conclusively that bees do use wax from foundations to extend both cell walls and midrib, that we are now ready to ask:

IS THE WAX OF THE MIDRIB OF THE FOUNDATION USED IN COMB BUILDING, AND, IF SO, WILL IT BE CUT DOWN TO THE THINNESS OF THE MIDRIB IN NATURAL COMB?

To determine these points we shall have to compare the thickness of the artificial foundation with the thickness of the comb midrib built upon the foundation, and the latter with the midrib of comb built entirely by the bees.

Table Showing the Weight, in Grains per Square Inch, of Different Kinds of Artificial Foundation, and of the Midribs of Comb Built upon Each.

Very Heavy Foundation		Medium Brood Foundation		1898 Deep-Cell Foundation*			Thin Super Foundation		Extra Thin Foundation		† 1899 Deep-Cell Foundation		* Midribs of Natural Worker Comb
Entire Foundation	Midribs of Comb on	Entire Foundation	Midribs of Comb on	Entire Foundation	Midribs of Foundation	Midribs of Comb on	Entire Foundation	Midribs of Comb on	Entire Foundation	Midribs of Comb on	Entire Foundation	Midribs of Comb on	
H. 12.	10.10	8.80	6.87	5.55	2.55	4.10	4.20	3.70	3.64	3.12	5.12	3.74	3.20
L. 10.	7.00	8.10	3.50	5.38	2.40	3.00	4.00	2.40	3.53	2.75	4.44	2.83	1.65
Ave. 11.	8.00	8.40	5.18	5.46	2.50	3.44	4.07	3.00	3.60	2.95	4.50	3.22	2.10
Heavier Than Natural Midrib.	5.90	—	3.08	—	.40	1.34	—	.90	—	.85	—	1.12	—

The accompanying table gives, in the upper line, the heaviest weights found; in the second line the lightest weights; and in the third line the average weights, computed from a good number of examples in each case. The excess in weight above that of the midrib of natural worker comb is given in the bottom line.

The differences in weight between these foundations and the midribs of comb built upon them do not represent the weight of the wax removed from the midrib of the foundation by the bees, as the foundation has short cell walls which are also thinned. These may be seen by looking at illustrations of sections of foundation in Plates 2 and 4. It will be seen by the table that none of the comb built on foundation has a midrib as light as that of the natural worker comb, though, in some cases, the midribs of comb on thin and extra thin super foundations and on the "1899" deep-cell foundation are but little heavier than those of natural comb.

It will also be noticed that, while the midrib of the "1898" deep-cell foundation itself was but little heavier than that of natural worker comb, the comb built upon this foundation had a midrib much heavier than that of the natural. The reason for this will be given directly. The table also shows that the heavier the midrib of the foundation, the heavier will be the midrib of the comb upon the foundation. This would be a general rule that might have exceptions.

* This foundation was obtained for experiment in 1898, when it was comparatively a new product, so I have called it "1898" deep-cell foundation to distinguish it from the foundation mentioned below.

† Samples of this foundation were first received in 1899, and I have designated it the "1899" deep-cell foundation to distinguish it from the preceding.

The above table shows that the very heavy foundation gave a comb midrib weighing 5.90 grains more to the square inch than the midrib of natural comb. Medium brood foundation gave a midrib 3.08 grains heavier to the square inch, or almost two and one-half times the weight of natural midrib. The lightest midribs were obtained by the use of extra thin and thin super foundations, averaging but .85 to .90 grains to the square inch more than natural midrib.

The use of the "1898" deep-cell foundation manufactured by Mr. E. B. Weed gave rather surprising results. The midrib from the foundation, before it had been worked over by the bees, averaged but .40 grains to the square inch more than the natural midrib, while the midrib of comb built on this foundation weighed 1.34 grains more. The midrib of this foundation was not uniform in thickness, in some places being thinner and in others thicker than in natural comb, as shown in Plate 4, Fig. *d*. Where the midrib was thick there was little or no thinning by the bees, but where it was very thin they reinforced the weak places by "plastering" on a quantity of wax. These thickened places are plainly shown at *n*, Fig. *c*, and at *f* of the plate just mentioned; and at *b* of Plate 1, and account for the increased weight of the comb midrib. Fig. *f*, just mentioned, is from one of the worst samples I have seen. Natural midrib is shown at *e*.

The difference in weight between the heavier artificial foundations and the midribs of the comb built upon them is too great to result from the thinning of the short cell walls alone, and can only be accounted for on the supposition that the bees do remove wax from the midribs of these foundations. The examination under a microscope of any heavy foundation that the bees have just begun to work will show the marks of their mandibles in the wax. At first the wax is left very rough, as shown in Plate 1, Fig. *g*, considerably magnified. At *h* is shown the smooth bottoms of the finished cells on the same foundation, which was medium brood in both cases.

To be convinced that heavy foundations have their midribs thinned, but not thinned to correspond with the midribs of natural comb, the reader has only to look at the figures in Plate 2. At *a* is shown a section of heavy foundation, and at *b* and *g* are shown midribs of comb built on this foundation. The lower third of *b* is a midrib of natural comb built on the foundation. At *c* and the lower end of *d* are shown sections of the medium brood foundation, while the upper portion of *d* and all of *e* show to what extent the midrib of this foundation was thinned. Notice also in this connection, that the full thinning of both foundation and cell walls is accomplished while the walls are yet quite short.

The fact that foundations are thinned was also shown by actual

measurements. A large number of *plaster casts of comb on different foundations and of the foundations themselves were made, and then cut in different directions as shown in Plates 2 and 5. This made it possible to cut the wax of the different cells so that the thickness could be measured. A large number of measurements were made and tabulated, but the variations are so great in thickness of both midribs and cell walls in all kinds of comb that I have thought it not worth while to include the table here, but will state the general results.

† The common range in thickness of the midrib in naturally built worker comb was found to be between .08 and .16 millimeters.‡ In drone comb the common range was between .12 and .20 millimeters. None of the midribs of comb built on artificial foundations averaged as thin as the natural midrib in worker comb. In some cases those from thin and extra thin super foundations, and the "1899" deep-cell foundation approximated it closely. Where the midrib of a foundation is not thicker than about .17 millimeters, the bees seem not to thin much if any, though they go over the surface with their mandibles and scrape it so that it loses its tranparency.

It was also noticed that the midrib of any comb was thicker near its attachment, at the top, sides or bottom, than at some distance from these attachments. Illustrations of this may be seen in Plates 2 and 3. Fig. *c* of the latter plate shows a cut through the comb of a pound section made from side to side.

The heavier midrib and cell walls in drone comb are necessary to give it the same strength as worker comb, because the larger the cells the fewer the number, and the smaller the amount of wax required to build them to a given thickness.

Sections of natural worker comb are shown at *b*, *c*, and *e*, and the lower halves of *a* and *g* of Plate 3. Drone comb is shown in the lower part of *i* in Plate 2, and in *f* of Plate 3.

The midrib of comb built on "1898" deep-cell foundation was very irregular in thickness, for the reasons already given, and averaged about the same as drone comb. See Plate 4, Figs. *c* and *f*. Medium brood foundation also gave wide variations in the amount of thinning.

At Plate 2, *d* and *e*, are two of the best thinned samples I have seen, though little drawn. At *f*, Plate 5, is a sample of fully drawn comb on this foundation which has the midrib thinned but little.

At *f*, Plate 2, is shown a section of super foundation obtained from Mr. Elliott, of Denver, and at *h* is a section through comb on

* I got this idea from Mr. E. R. Root, Editor of "Gleanings in Bee Culture."

† I have not found any samples of natural comb with as heavy cell walls as those shown on page 69 of "A, B, C of Bee Culture," Figs. 1 and 2.

‡ Reduce millimeters to inches by dividing by 25.

this foundation. The midrib averages about .17 millimeters in thickness, or fully as heavy as the midrib in drone comb. The upper half of *i* in this plate is also on this foundation, and the midrib is rather heavier than the midrib of the drone comb which the bees built, shown in the lower half of the figure.

At *j* of Plate 2 is shown a section of thin, and at *l* of the extra thin super foundations. The two differ chiefly in that the former has rather heavy cell walls, while the extra thin has almost no walls. At *k* is a section showing partially drawn comb on the thin super foundation, and at *g*, Plate 5, is a sample of fully drawn comb on the extra thin foundation. It will be noticed that the midribs of the comb samples built on these foundations are in most cases nearly, if not quite, as thick as in the foundations themselves. At *a* of Plate 3 is a section through comb, the upper two-fifths of which was built upon the thin super foundation and the lower three-fifths is natural. The midrib of the foundation seems not to have been thinned at all, and contrasts plainly with the midrib of the portion that was built entirely by the bees, and also with the midribs of figures *b* and *c* of the same plate, both of which represent natural comb.

At *g* of Plate 4 is shown a section of the beautiful "1899" deep-cell foundation, as I have termed it, that is manufactured by Mr. E. B. Weed. At *h* of the same plate is shown comb slightly worked on this foundation, and at *a* of Plate 5 is shown fully drawn comb on the same. Here again it will be noticed that the midrib is scarcely if at all thinned, and is as heavy as that of drone comb.

The evidence thus obtained by measuring the thickness of the midribs of foundations and of the comb built upon them bears out the results obtained by weighing, namely, that heavy foundations have their midribs thinned some, usually much, by the bees when they build comb upon them; but these are not thinned, in any case, to the lightness of natural worker comb. If the midrib is not thicker than .17 millimeters—.068 of an inch—the bees thin it little if any; if the midrib is much thinner than the normal, the bees are likely to thicken it by the addition of wax, making it much heavier than in natural comb.

DOES THE USE OF ARTIFICIAL FOUNDATIONS RESULT IN THICKER CELL WALLS IN THE COMB?

It is evident that a slight thickening of the cell walls increases the weight of the comb more than the same thickening of the midrib. *Cheshire estimated that the area of the cell walls of worker comb one inch thick is fully ten times that of the midrib upon which they are built. If this be true (and the difference in area is

* "Bees and Bee-keeping," Vol. II., page 213.

greater when the comb is more than an inch thick), then the thickening of the cell wall by .01 of a millimeter increases the weight of comb one inch thick as much as thickening the midrib .10 of a millimeter.

The thickness of the cell walls is much less than that of the midrib. In natural worker comb I have found it varying between .045 and .07 of a millimeter, with an average of not more than .06 of a millimeter (.0024 of an inch). It has been thought by some that, though the bees may leave a heavy midrib in comb built on foundation, they will thin the cell walls down to the thickness in natural comb.

Although the cell walls of a large number of sections of comb have been measured under the camera of a compound microscope, it is difficult to give these in tabulated form, as there is so much irregularity in thickness. The heaviest part, except the extreme outer end, is close to the base of the cell, and the thinnest is beyond the middle of its length. Where comb on heavy foundations was studied, the bases of the cells were found to have distinctly thickened walls for some distance out, and this thickening was often quite irregular, as may be seen at *o* in Figures *g*, *h*, and *i* of Plate 2, and Figure *b* of Plate 4.

None of the foundations used in the experiment gave as delicately thin cell walls as are found in natural worker comb, except the thin and extra thin super foundations and, possibly, the rather shallow deep-cell foundation put out in 1899, which was placed upon the market by the A. I. Root Co., and which is being sold quite largely this year. I was not able in many cases to detect by measurements that the cell walls on these foundations exceeded the average thickness in natural comb. The difference, if any, is very slight. Figure *g* in Plate 4 shows the thickness of the cell walls of this foundation in cross section, and at *b* of Plate 5 is shown a section of the walls parallel to the midrib and quite close to it. Figure *a* of Plate 5 is a section of fully drawn comb on this foundation, and it will be seen that the cell walls have nearly, or quite, the delicacy of those in natural comb.

The "1898" deep-cell foundation with considerably longer cell walls, as shown at *d* of Plate 4, was not nearly so well worked according to my measurements. This may be due to the fact that the walls are so high that the bees cannot reach to the bottom with their mandibles to take hold of them and pinch them to the natural thinness. They can only thin the lower portion of the walls by scraping them. As a rule, I have found the lower portion of the cell walls of comb on this foundation as thick as those built on the very heavy foundations, while in some cases they have been thinned very nearly to the delicacy of the walls in natural comb. A good illustration of the latter case is shown at the upper half of *a* of Plate 4, but even this sample compared with natural worker comb

shows a difference in favor of the latter which is hardly noticeable in the photographic reproduction. On the other hand, the illustrations of sections of cell walls on this foundation shown at *d*, Plate 3, and at *c* and *f*, Plate 4, show plainly the abnormal thickness of the inner third or half of the cell walls as compared with the walls in natural comb shown in *b*, *c*, and *e* of Plate 3. In fact, a close inspection will show that in many cases the walls of the comb cells seem not to be thinner than the walls in the cells of the foundation before the bees have touched them. In all cases, with this foundation, I have found the walls of the comb cells thicker than in natural worker comb. At *i*, Plate 5, is shown a portion of Figure *d*, Plate 3, somewhat magnified. Notice the thickness of the cell walls in their basal portion.

The cell walls in Figure *h* and the upper half of *i* of Plate 2, and the upper third of *g* in Plate 3, were built on the foundation shown at *f* of Plate 2. The foundation, it will be seen, is almost without walls, yet the bases, at least, of the cell walls in the comb can be seen by the unaided eye to be sensibly thicker than in the natural comb samples.

It seems, then, that keeping the wax out of the cell walls does not entirely remedy the tendency to build heavier bases to the cell walls when plenty of wax is at hand. I do not have a test, however, on strictly "no-wall" foundation, but cannot think the case would be different than in the use of this foundation with such slight walls.

The medium brood and the very heavy foundations also gave cell walls decidedly thicker than those found in natural comb. Examples of cell walls on medium brood foundation are shown at *d* of Plate 2, and at *f* of Plate 5. In the two first mentioned figures the walls are made thinner than in the long drawn cells of the last named example. All are heavier than in natural comb.

At *g* of Plate 2 and *b* of Plate 4 are shown examples of comb on the very heavy foundation. In both cases the greater thickness of the walls is very plainly seen. In the first mentioned figure the heavy walls extend, plainly, the entire length of the cells. Compare with sections of natural comb cells in Plate 3.

These studies indicate that it is a mistake to make very deep cells in artificial foundation, unless their walls can be brought down to the thinness of the naturally built cell walls—which is probably impossible—otherwise, the bees will leave them thicker than in the natural comb. The only cell walls that were brought, practically, to the thinness of the natural comb were those built on foundations with a light base and with little wax in the cell walls. The deep cells may be of advantage in other ways, but not in getting a light comb for section honey.

COMPARATIVE WEIGHTS OF NATURAL COMB AND COMB ON ARTIFICIAL FOUNDATIONS.

There is a third method of studying the effect of foundations upon the resulting comb which, to my mind, gives the most convincing evidence. By this method pieces of natural comb and comb on different kinds of foundation were cut into blocks of known area and carefully weighed. Then the cell walls were removed from the midribs and the weight of these two portions determined separately. Then the weights of the midribs and cell walls of natural comb were compared with the corresponding parts of comb built on artificial foundations, and the midribs of the latter with their corresponding foundation midribs. In this way I was able to determine whether the cell walls or the midribs of comb on artificial foundations were as light as in the natural comb.

Table Giving Weights, in Grains to the Square Inch, of Whole Comb and of the Midribs and Cell Walls of the Comb, in Each Case Separate.

Kind of Foundation.	Thickness of Comb.	Weight of Comb.	Weight of Midrib.	Weight of Cells.	Sq.ft ofComb to make 1 lb. of Wax.
Natural Worker Comb.....	1.37	13.00	2.20	10.80	3.74
" " "	1.35	12.90	2.50	10.40	3.76
" " "	1.33	12.20	2.20	10.00	3.99
" " "	1.25	12.80	2.30	10.50	3.80
" " "	1.25	10.90	2.20	8.70	4.46
" " "	1.20	9.50	2.00	7.50	5 12
" " "	1.18	9.60	2.15	7.45	5.09
" " "	1 15	9.55	1.80	7 75	5.09
" " "	1.13	9.55	2.33	7.22	5.06
" " "	1.00	10.00	2.50	7.50	4 86
" " "	.90	9.00	2.00	7.00	5.40
" " "	.90	7.60	1.80	5.80	6.40
" " "	.80	7.00	1.80	5.20	6.94
" " "	.75	6.60	1 90	4.70	7.37
" " "	.66	6.40	1.75	4.65	7.60
" Drone "	.93	10.75	3.55	7.20	4.52
" " "	.90	11.25	3.50	7.75	4.32
" " "	.88	9.90	2.80	7.10	4.91
Extra Thin "	1.25	11.90	2.75	9.15	4.08
" " "	1.22	10.61	2.33	8.28	4.58
" " "	.73	7.15	3 12	4.03	6.80
" " "	.60	7.15	3.07	4.08	6.80
Thin Super (A) "	1.25	13.00	2 40	10.60	3.74
" " " "	1.25	11.50	2.60	8.90	4.23
" " " "	1.20	11.50	3.00	8.50	4.23
" " " "	1.00	10.20	2.80	7 40	4.77
" " " "	.25	5.80	2.70	3.10	8 38
" " (B) "	.90	11.50	4.00	7.50	4.23
" " " "	.75	9.40	3.30	6.10	5.17
" " " "	.75	9.35	2.90	6 45	5.20
" " " "	.75	9.10	2.70	6.40	5.34
1898 Deep Cell "	1.46	16.80	3.60	13.20	2.89
" " " "	1.44	16.63	3.70	12.93	2.92
" " " "	1.13	14.90	3.30	11.60	3.26
" " " "	.56	10.25	3.40	6.85	4.74
" " " "	.50	10.00	4.00	6.00	4 86
1899 " " "	1.50	14.50	2.83	11.67	3.32
" " " "	1.31	13.33	3.33	10.00	3.65
" " " "	.75	11.51	3.74	7.77	4.23
" " " "	.31	6.00	3.00	3.00	8.10
Medium Brood "	1.30	19.50	6.87	12.63	2.49
" " "	1.20	19.12	6.12	13.00	2.54
" " "	1.06	16.50	6.23	10.26	2.95
" " "	1.00	16.50	5.50	11.00	2.95
" " "	.75	12.00	5.35	6.65	4.05
" " "	.75	13.00	5.20	7.80	3.74
" " "	.38	7.50	3.50	4.00	6.48
*Very Heavy "	1.00	18.50	7.00	11.50	2.63
" " "	.95	18.33	8.00	10.33	2.65

* This line is an average of pieces composing 15 square inches of comb.

In the preceding table all the weights obtained from the pieces of comb are given.

The first fifteen examples in the table are of worker comb as built by the bees in the natural way. The three following are naturally built drone comb.

The extra thin foundation weighed but 3.60 grains to the square inch, or 13.50 square feet to the pound, and had very slight cell walls. It is shown at *l* of Plate 2 in cross section.

The foundation listed as "Thin Super (A)" weighed almost exactly four grains to the square inch, or a trifle more than twelve square feet to the pound, and was rather firm in texture. It is shown in cross section at *j* of Plate 2.

That listed as 'Thin Super (B)" was of the same weight as the preceding, but of softer texture and had more wax in the midrib and less, almost none, in the short walls. It is shown in cross section at *f*, Plate 2.

The "1898" deep-cell foundation is the kind shown at *d* of Plate 4. It ran about 5.46 grains to the square inch, or approximately, nine square feet to the pound.

The "1899" deep-cell foundation is that shown in Figure *g* of Plate 4, and it weighed 5.10 grains to the square inch or 9.53 square feet to the pound.

The medium brood foundation weighed 8.40 grains to the square inch, or 5.80 square feet to the pound. It is shown at *c* of Plate 2.

The very heavy foundation averaged 11 grains to the square inch, or 4.42 square feet to the pound, and is shown at *a*, Plate 2.

The thickness of the comb samples in each case is given in the second column in the table, and is stated in inches and hundredths.

The third column gives the weights in grains to the square inch of the samples used, and is the sum of the weights in columns four and five, which give the weights of the midribs and the cell walls respectively.

The column at the right gives the number of square feet of each sample of comb that would be required to weigh one pound.

Each sample was of whole comb, *i. e.*, comb drawn to a greater or less thickness but not capped, so that the cells were complete as built.

It would have been better, or at least easier, to compare samples of comb of the same thickness; but comb varies so much in this respect that it was found impossible to do so with the samples at hand in the experimental apiary, and the evidence desired seems to be fairly ample in the data obtained and given in the preceding table.

First, I will call attention to the fact that the three samples of drone comb, varying between .88 and .93 of an inch in thickness,

are considerably heavier than samples of natural worker comb of approximately the same thickness.

The sample of comb 1.25 inches thick on extra thin super foundation is but .10 of a grain heavier than the average of the two samples of natural comb of the same thickness. The sample 1.22 inches thick is fully as light in proportion to its thickness. The two thinner comb samples on this foundation do not compare quite as favorably with the natural.

The thickest sample of natural comb measured 1.37 inches, and weighed 13 grains to the square inch. No sample on artificial foundation as thick weighed so little, while one sample 1.25 inches thick on thin super foundation (A) weighed the same. All samples over .75 of an inch thick on medium brood and very heavy foundations weighed from about one-fourth to two-thirds heavier, or from 16.50 to 19.50 grains to the square inch. The sample 1.13 inches thick on deep-cell foundation put out in 1898 exceeds in weight the thickest sample of natural comb by 1.9 grains to the square inch.

The samples of natural comb 1.34 and 1.33 of an inch thick are also exceeded in weight by the same thinner samples of comb on artificial foundations just mentioned.

The heavier sample of natural comb measuring 1.25 inches thick is exceeded in lightness by one sample of comb on thin super foundation of the same thickness, while the other sample of the latter is heavier than the natural.

The two thickest samples of comb on "1898" deep-cell foundation average one-seventeenth thicker than the thickest sample of natural comb, but their weights average more than one-fourth heavier than those of the latter. Their comparsion with the next two samples of worker comb would be still less favorable to the foundation.

The sample of natural comb measuring 1.13 inches thick seems not to be unusually light, as the sample 1.15 thick weighed no more; the one that was 1.18 thick hardly exceeded it, and the one 1.20 thick weighed even less. Comparing this comb with the sample of the same thickness on the "1898" deep-cell foundation, we find the latter is heavier than the former by more than one-half the weight of the natural comb. In other words, it is heavier than the natural comb by almost exactly the weight of the deep-cell foundation. The two samples of comb on this foundation that are .60 and .56 of an inch thick respectively are as heavy or heavier than any of the samples of natural worker comb measuring from 1.20 inches in thickness down.

The "1899" deep-cell foundation produced a comb much nearer the natural in lightness. Comparing the sample 1.50 inches thick with the natural sample 1.37 thick, we see there is but 1.50 grains difference in weight, which would be fully accounted for by the greater

thickness of the comb in the case of the latter. Comparing with the two thickest samples of comb on the "1898" deep-cell foundation, either of which is thinner than the "1899" sample, we notice that the latter is, nevertheless, considerably lighter in weight.

If we compare the sample of comb 1.31 inches thick on the "1899" deep-cell foundation with the samples of natural comb measuring 1.33 and 1.35 inches respectively, we find a good margin of difference in favor of the natural samples, although they are somewhat thicker than the example on foundation.

These comparisions bring us again to the conclusion that, of the samples of foundation that we have studied, the thin and extra thin super, and the "1899" deep-cell foundations, are far the best for the production of a comb to compare in quality and lightness with natural comb.

* Now, if we examine columns four and five we shall see that the increased weights of the examples of comb on artificial foundations were due more to the extra wax in the cell walls than to the increased amount of wax in the midribs in cases of the heavy foundations, but not in cases of the thin and extra thin super, or "1899" deep-cell foundations. I will call attention to a few examples and the reader may compare others.

Beginning with the heaviest foundations first, it will be seen that the comb cells in the sample one inch thick weighed 11.50 grains, against 7.50 grains in the case of the natural comb of the same thickness. In case of comb one inch thick on medium brood foundation, the cells weighed 11.00 grains to the square inch.

Take the samples of the same kinds of comb that are .75 of an inch in thickness and the weights of cell walls are, for natural comb, 4.70 grains; for comb on medium brood foundation, 6.65 grains; and for comb on very heavy foundation, 7.80 grains. It will also be noticed that the two samples of comb on "1898" deep-cell foundation that were less than .75 of an inch thick had cell walls that were considerably heavier than the natural comb that was of that thickness.

If we combine the two samples of medium brood comb, one measuring 1.30 and the other 1.20 inches thick, we shall have an average of a sample 1.25 inches thick, the cells of which weigh 12.81 grains to the square inch. Comparing this with the weights of the cells of the natural comb samples of the same thickness, we find it exceeds the heavier by 2.31 grains, and is almost one and one-half

* In "A, B, C of Bee Culture," p. 67, Mr. E. B. Weed is reported to have discovered "That in ordinary foundations upon the market, there was too much wax in the base (midrib) and not enough in the wall; that whenever the base is thicker than the bees make it they will rarely take the trouble to thin it down; but, no matter how thick the wall, they will invariably thin it down to the thickness of the natural." Both these statements need to be much modified, according to the experiments here reported.

times the weight of the lighter. It even exceeds the weight of the thickest of the natural comb samples by 2.01 grains.

If we take the comb cells on "1898" deep-cell foundation that measured 1.13 of an inch thick and compare their weight with the sample of like thickness of natural comb, we see that the cells of the latter are lighter by 4.38 grains. In fact the cell walls of this sample of deep-cell foundation exceed in weight any of those of the seven thicker samples of natural comb.

The comb samples on the "1899" deep-cell foundation had cell walls that compare very favorably with the natural comb in lightness. The comb 1.31 inches thick on this foundation had cells that weighed exactly the same as cells of natural comb that was 1.33 inches thick, and the cells from the sample 1.50 inches thick did not weigh more than would be expected for natural comb. The sample of comb .75 of an inch thick on this foundation does not compare so favorably in weight of its cells.

If we pass to the comb on thin super foundations we again find very satisfactory comparisons. The cells from comb 1 inch thick and from comb 1.20 inches thick weighed only a trifle more from the foundation than from natural comb. The same is true of the average of the two samples in each case that were 1.25 inches thick. The differences being so slight, go to show that there is practically no difference in the weight of cell walls of natural comb and comb of the same thickness on the thin super foundation.

The samples of comb on extra thin foundation compare equally well with natural comb in the lightness of their cell walls, as may be seen by the table.

By comparing the weights of the comb midribs given in column four, it will be seen that the lightest midribs from comb on foundation are not quite as heavy as the heaviest midribs in natural worker comb, but in every case they are heavier than the average weight (2.10 grains to the square inch) of the midrib of natural comb.

With this additional evidence, it seems impossible to avoid the conclusion that heavy foundations result in combs heavier than the natural, and that the increased weight is due both to thicker midribs and heavier cell walls, but much more to the latter than to the former in cases where heavy foundations are employed, even though much wax is left unused in the midrib.

The experiments show that to get a light comb, approaching that which the bees naturally build, there must not be a large amount of wax in either the midrib or cell walls of the foundation.

The evidence is also quite conclusive that if the cell walls are very high, as in the "1898" deep-cell foundation, they will not often be well thinned in the building of the comb.

TO WHAT EXTENT DOES THE FOUNDATION LESSEN THE SECRETION OF WAX BY THE BEES?

Let us begin with the comb built on the heavier foundations and compare with the naturally built worker comb, to determine the effect on wax secretion.

Natural worker comb 1 inch thick weighed 10.00 grains to the square inch. The very heavy foundation alone weighed 11.00 grains, or 1 grain more than is necessary to build the comb to that thickness. But when comb was built on this thick foundation, it weighed 18.50 grains, so that the bees added 7.50 grains to the square inch to the foundation that itself contained more wax than was necessary to build the comb. As natural comb weighs but 10.00 grains to the square inch, the bees lacked but 2.50 grains of furnishing as much wax as they would have done if they had built the comb without the foundation. *It is seen that 11.00 grains of wax were furnished the bees in order to save them the expense in food and labor of producing 2.50 grains.

In case of the medium brood foundation weighing 8.40 grains to the square inch, the result was similar. The bees needed to add but 1.60 grains to this to build the comb one inch thick, but they did add 8.10 grains, making a comb weighing 16.50 grains to the square inch. As the amount added in this case is only 1.90 grains less than the weight of the natural comb of the same thickness, it cost the whole weight of the foundation, or 8.40 grains, to save the bees from secreting 1.90 grains of wax.

As another illustration with this same foundation, take the samples drawn to .75 of an inch. The average weight would be 12.50 grains. This is 5.90 grains more than the weight of samples of natural comb drawn to the same thickness, and 4.10 grains more than the weight of the foundation alone, notwithstanding the fact that the foundation as given the bees contained 1.80 grains to the square inch more wax than was necessary to build natural comb to that thickness. In other words, the bees were furnished more wax than was necessary to build the comb three-quarters of an inch thick, and yet they added to this amount more than nine-tenths as much wax as they would have used to build the comb without foundation.

Passing now to the Weed deep-cell foundation manufactured in 1898, we find results fully as surprising. If we compare the sample measuring 1.13 inches thick with natural comb of the same thickness, we find that the latter is lighter by 5.35 grains. As the foundation itself weighed only 5.46 grains to the square inch, the indication is that the bees used as much wax from their own secret-

* Cheshire says "Bees very rarely work more than half their cell walls out of even the stoutest sheets given them."—*Bees and Bee Culture*, V. II., p. 216.

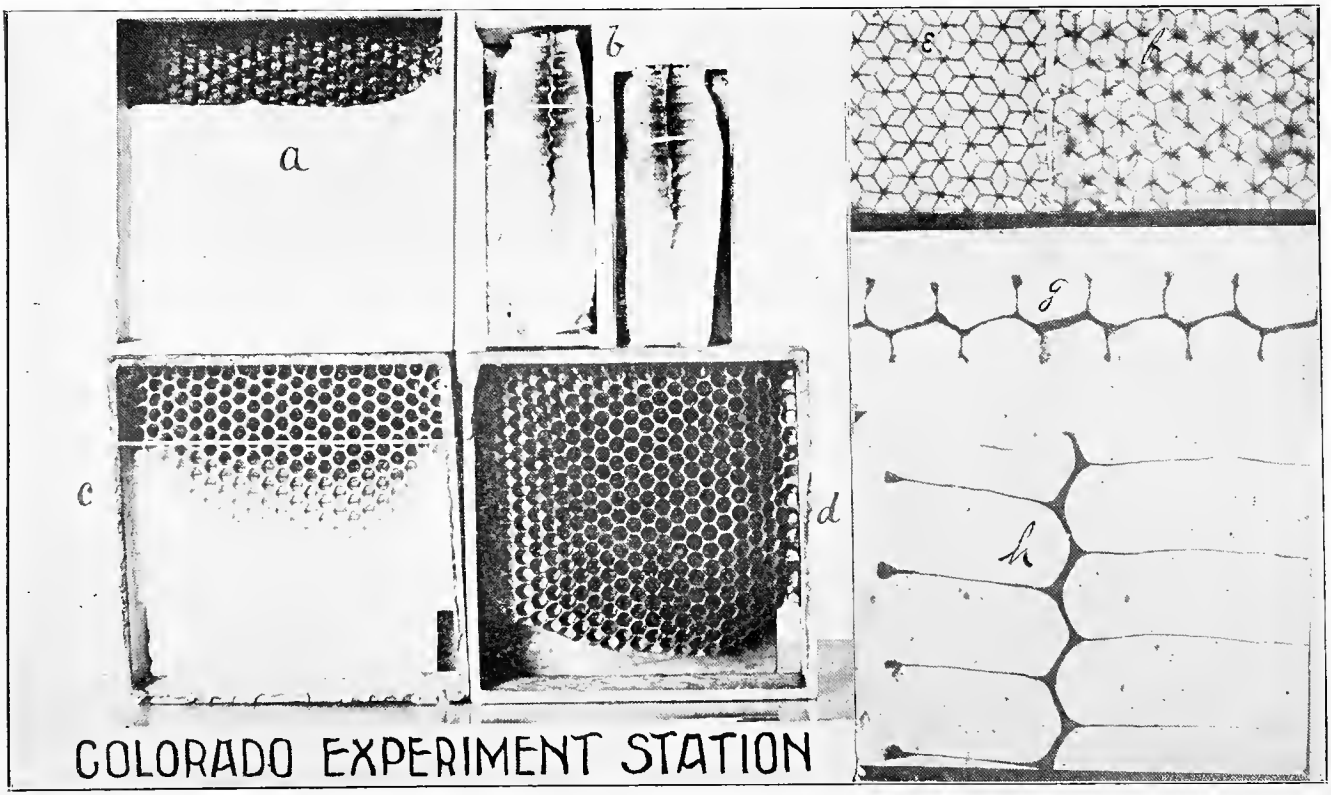

Plate 1.

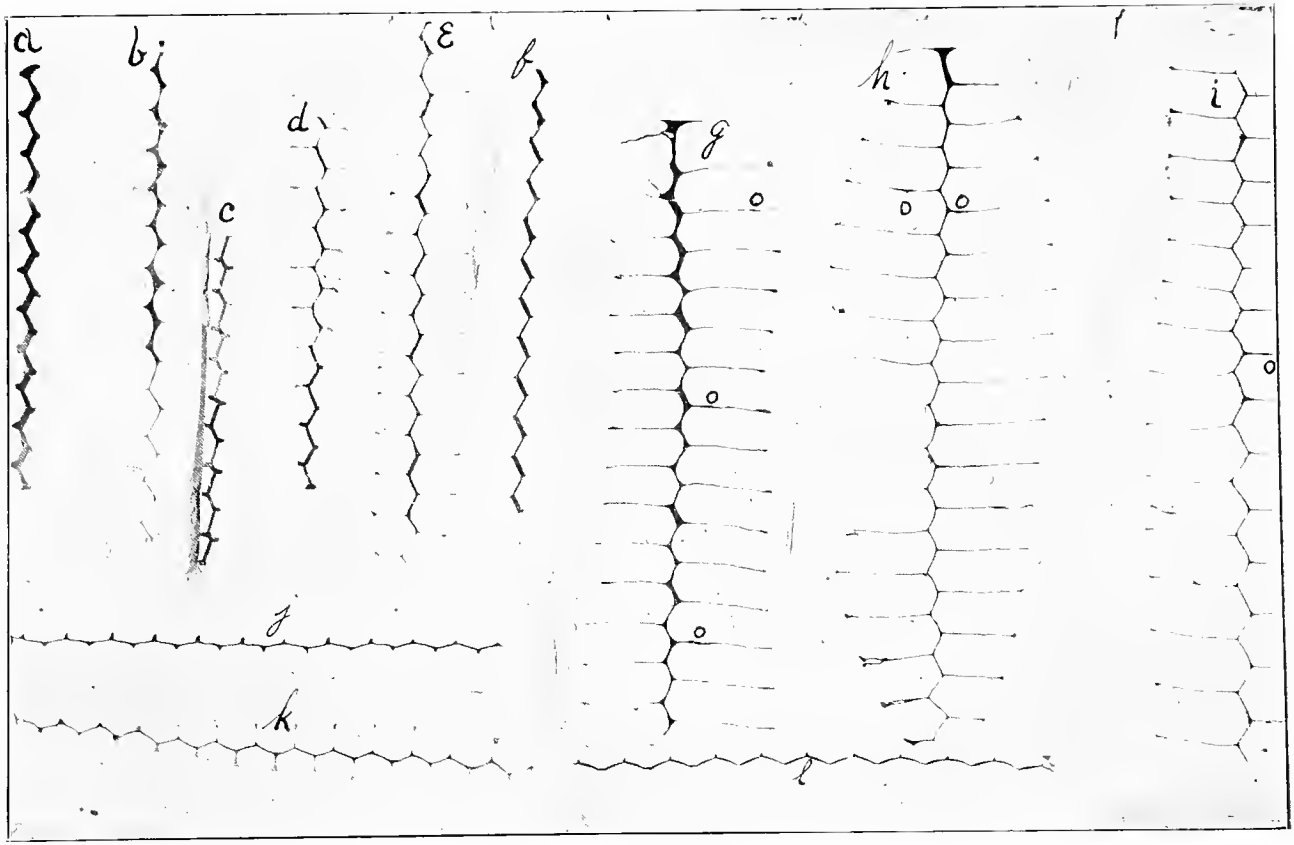

Plate 2.

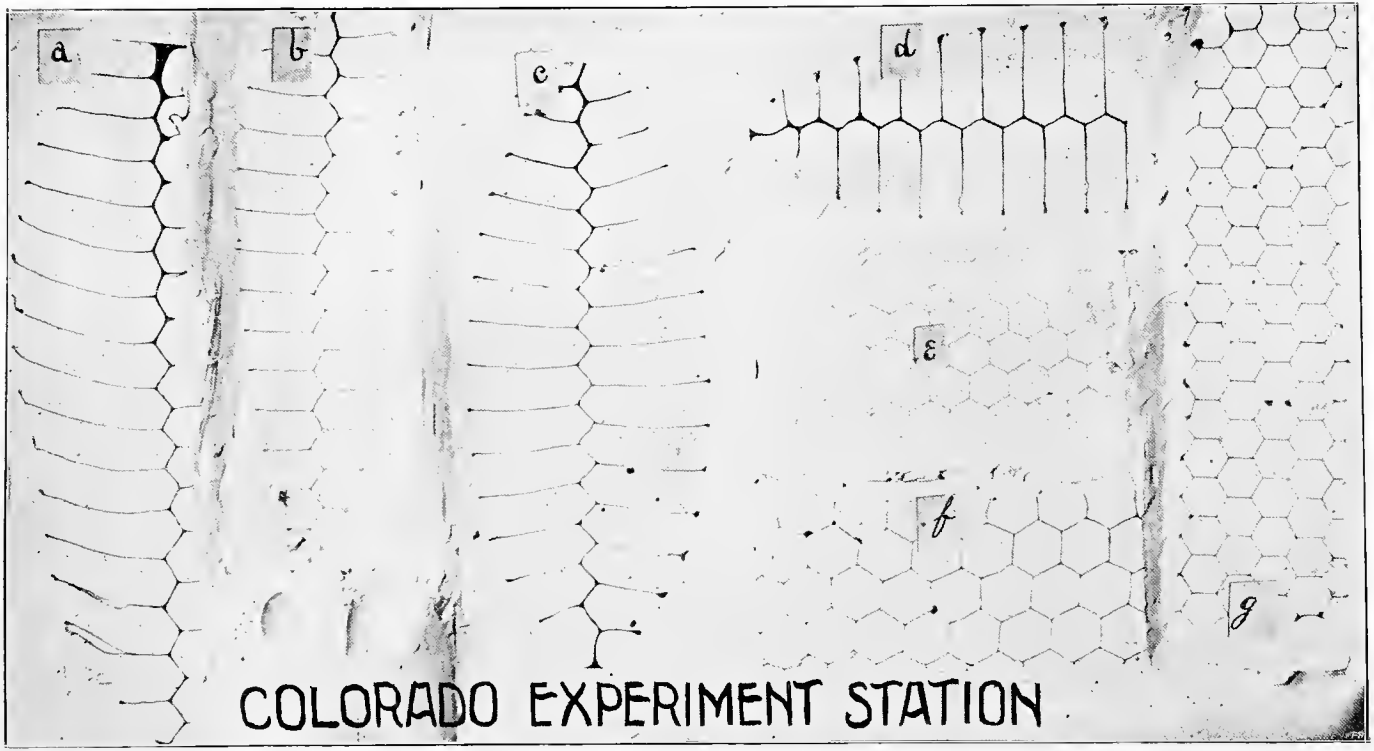

PLATE 3.

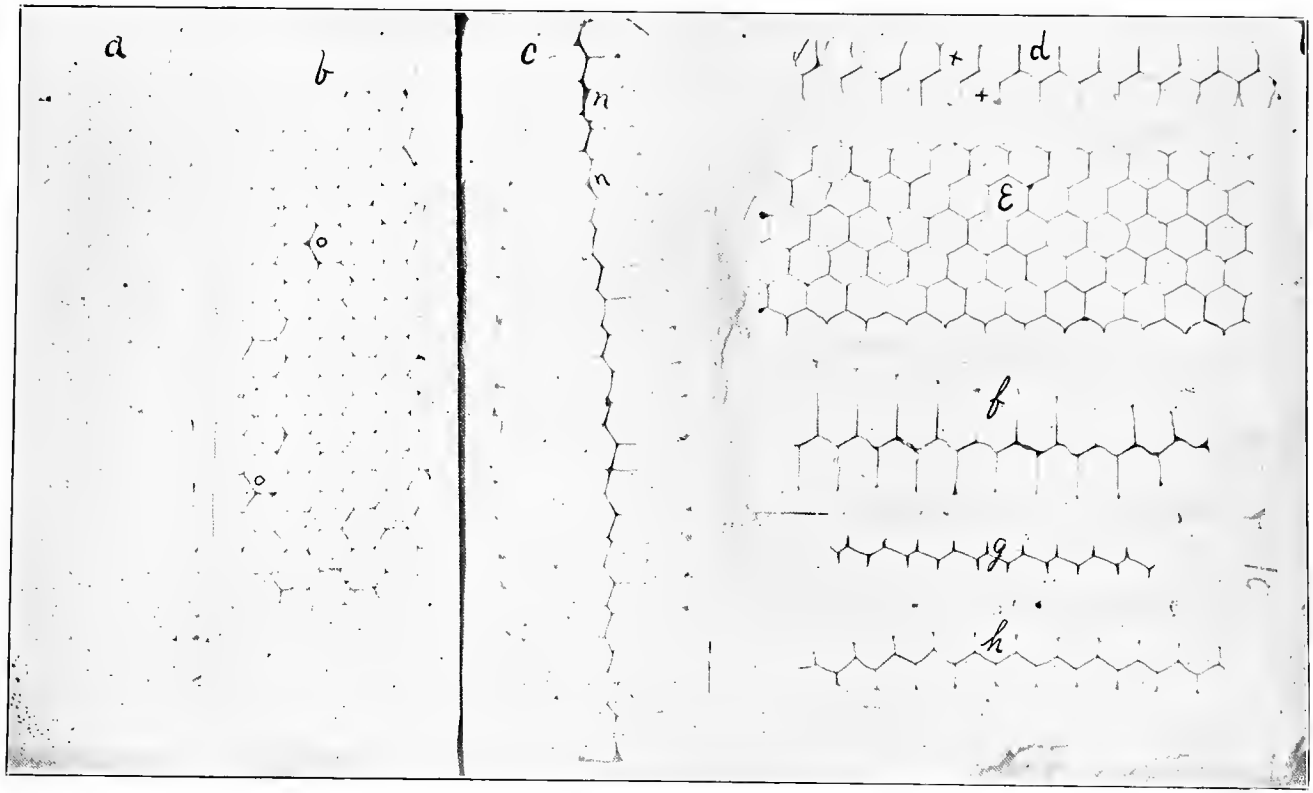

Plate 4.

ing within .11 of a grain, as they would have done if no foundation had been given.

The samples of comb .56 and .60 of an inch thick on this foundation contain enough wax to make a natural comb one inch thick, and nearly half of the weight was added by the bees.

Reliable results are not so readily obtained in the study of comb samples on the light foundations, as the amount of wax in them is small and the natural variation in comb samples is considerable.

The thickest sample on the thin super foundation (B) was only .90 of an inch. To get as near an average weight of the natural comb as possible for comparison, let us combine the two examples that measure .90 of an inch each with those measuring respectively 1.00 and .80 of an inch. The average would be 8.40 grains to the square inch. The difference between this and the sample on this foundation is 3.10 grains. As the foundation itself weighed 4.00 grains to the square inch, the indication in this case is that the saving to the bees was the difference between these weights, or .90 of a grain to a square inch, or about 23 per cent. of the amount of wax given.

Far better results were obtained in the use of thin super foundation (A), the average weight of which was 4.07 grains to the square inch.

Comparing comb 1 inch thick on this foundation with natural comb of the same thickness, we find, in case of one of the samples in the table, there is but .20 of a grain difference in favor of the latter. This means that this foundation lessened the amount of wax that the bees secreted, by 95 per cent. of its own weight.

The above may have been rather an exceptional piece on the thin foundation. If we compare the sample that measured 1.20 inches in thickness with a similar sample of natural comb, we find a difference of 2 grains to the square inch. As the foundation was almost exactly twice this weight, it indicates that the bees were relieved from secreting an amount of wax equal to half the weight of foundation given.

It is important to notice that to build the comb on this foundation to the thickness of 1.20 inches, the bees added the difference between 11.50 and 4.07 grains to the square inch, which would be 7.43 grains, and this is actually less than they added in cases where they built comb to a thickness of only one inch on the very heavy and the medium brood foundations, and to a thickness of 1.13 inches on the deep-cell foundation, though in any one of these last three cases they were furnished more wax to start with.

Again, if we take the average of the two samples of comb on this thin foundation that were 1.25 inches thick and compare it with an average of the two samples of natural comb of the same thickness, we find that the latter is .40 of a grain lighter to the square inch

than the former. This would indicate that 90 per cent. of the foundation was utilized by the bees in making a comb but slightly heavier than the natural. We also find that the bees actually added less to this foundation in order to draw it out to 1.25 inches in thickness than in cases where they built comb to a thickness of an inch on the heavy and medium brood foundations. Further experiments are needed bearing upon this point.

If we compare the comb built on the "1899" deep-cell foundation and the extra thin super foundation with the natural comb, we find results nearly, or quite as good as the preceding. For examples, the comb 1.31 inches thick on the deep-cell foundation was but 1.13 grains heavier than the natural sample 1.33 inches thick, and the sample on this foundation that was 1.50 thick exceeded the weight of natural comb 1.37 inches thick by only 1.50 grains.

In case of the comb on extra thin foundation, the sample that was 1.22 inches thick weighed but 1.11 grains to the square inch more than the natural sample that measured 1.20 inches thick; and the sample on this foundation 1.25 inches thick is almost exactly an average of the two pieces of natural comb of the same thickness.

It seems, then, from all the evidence furnished by the forty-nine samples of comb listed in the preceding table, that we do not lessen the wax secretion of the bees much, if any, more when we furnish them a heavy foundation than when we furnish them a very light foundation.

These differences between the heavy and light foundations for comb building seem quite remarkable, and in a large series of samples might not result so much in favor of the light foundations; but the samples recorded in the table were taken without any attempt or thought of favoring one form or weight over another.

The writer believes it is a matter of much importance to bee-keepers to produce comb honey with as small an amount of wax as possible. They will, in this way, increase the consumption of their product, as many people object to comb honey because of the large amount of wax they often find in it.

METHODS OF USING FOUNDATION IN SECTIONS.

It is necessary to use some foundation in sections for comb honey. The best size and form of the piece of foundation to be used as a "starter" is not universally agreed upon, some preferring one form and some another.

The different methods of applying these starters, shown in Figures *a* to *g* of Plate VI., have been tested in the College Apiary for the past three years.

There was no appreciable difference in the comb produced by using starters in the manners shown by Figures *a*, *c* and *d*. The only advantage in the long, narrow piece, shown at *e*, was that it had

a tendency to secure the building of worker comb throughout. It has one disadvantage, and that is its large size and short line of attachment, so that if it is not well secured at the top the bees are liable to cluster upon it and pull it loose. The long, narrow piece placed across the top of the section, Figure *f*, has given rather better results than any of the preceding, as the bees usually attach it quickly at the ends, thus closing the top corners. I have also used many starters like the preceding, but extending about half way down. Figures *h*, *i* and *j* represent comb on such starters. It will be noticed there are no holes in the upper corner or sides. At *n* is a section of comb built on a full-sized starter, as shown at *g*. It will be noticed that the comb cells are all uniform in size and the comb evenly filled out. Such comb when filled and capped, is handsome in appearance, like the samples shown at *s*, and brings the highest market price. In my experiments the sheets that extended half way down gave as good results as those that filled the section. The use of small pieces of foundation in the lower corners, as shown at Figure *c*, gave no beneficial results.

The use of short strips of foundation in the middle of the bottom of the section, as shown at *b*, has resulted in somewhat better attached combs at the bottom of the section, especially during a slow honey flow.

Figures *k*, *l* and *m* show how comb is usually extended from a small piece of foundation, leaving, very often, holes in both upper corners. If the honey is coming in slowly and the colony is not very strong, the sections are liable to be finished like the two shown at *o* and *p* of the same plate. Not only are these sections light in weight and slow to sell, but they will not ship well, for the jar of handling will break many from their attachments in the sections. I have found, however, that such sections of honey are due much more to a weak condition of the colony and a poor honey flow than to the manner of using foundation. Under such conditions even large pieces of foundation are often gnawed away, as shown at Figures *q* and *r*. When the colony is strong and the honey flow good, small pieces of foundation, like the one shown at *a*, will often produce just as finely filled sections as can be obtained from full-sized pieces with strips below. Moral: Keep the colonies strong.

Comb built upon foundation is always tougher and more waxy than the natural comb, and a cross-section will show that the midrib and bases of the cells are darker in color. So that while the large pieces of foundation result in a somewhat finer appearing capped honey, the small starters will result in a more delicate and brittle comb.

ADVANTAGES FROM THE USE OF SEPARATORS.

Most producers of comb honey recognize the advantage in the use of thin strips of wood or tin between the rows of sections in the

supers. Without them the comb is sure to be uneven in a large proportion of the sections, and in many cases it will be bulged so as to make it very difficult to pack the sections in a crate for shipment. Illustrations of such sections are shown at *h* of Plate 5. These sections also vary much in weight, some weighing considerably more than a pound, while others weigh as much less. They are not as attractive nor as easily handled upon the market as those that are built with flat faces that do not project beyond the edges of the section, and that are all uniform in weight and appearance, as shown at *s* of Plate 6. I have used the tin and board separators in about equal numbers and have been unable to see that one has any special advantage over the other.

I have also used separators upon one side and upon both sides of the sections. While very good sections of honey are obtained by the use of separators upon one side only, the results have been enough better when used upon both sides to make the latter plan advisable. In my experiments the sections that had no separators averaged one-half ounce more in weight than those with separators on one side only, and the latter weighed one-half ounce more than the sections that had separators on both sides. As these lighter, better appearing sections sell better than the heavier, ill appearing ones, there is a double advantage in their production.

PROPORTION OF WAX IN COMB HONEY.

Beeswax does not melt at the temperature of the body and is indigestible in the human stomach. Although this does not necessarily imply that beeswax is harmful in food, it becomes a matter of some interest to know how much wax is taken with ordinary comb honey when the latter is eaten. It is also a matter of interest to know how much wax the bees are compelled to secrete for every pound of honey that they store in the natural way.

As a thick comb has but one midrib, and as the walls of the cells are heavier near the midrib than they are towards their outer portions, it is evident that comb one and one-half inches thick would not be half heavier than comb one inch thick. The increased weight of the thicker comb would be due entirely to the additional wax required to extend the walls of the cells one-half inch, and to that only. On the other hand, it is equally evident that the honey filling a comb one and one-half inches thick would weigh half more than honey filling a comb one inch thick. Consequently the weight of wax in thick combs is less in proportion than in thin combs. The weights given in the following table shows this to be true:

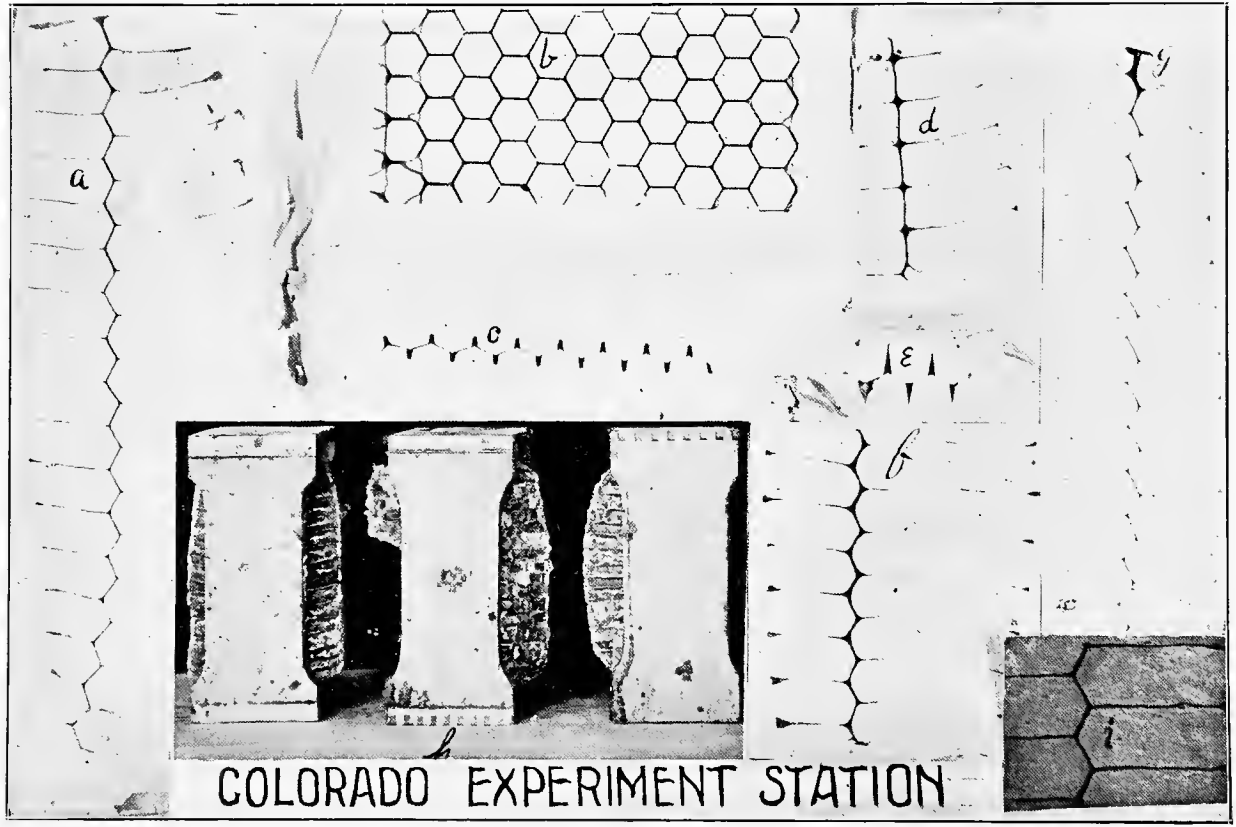

PLATE 5.

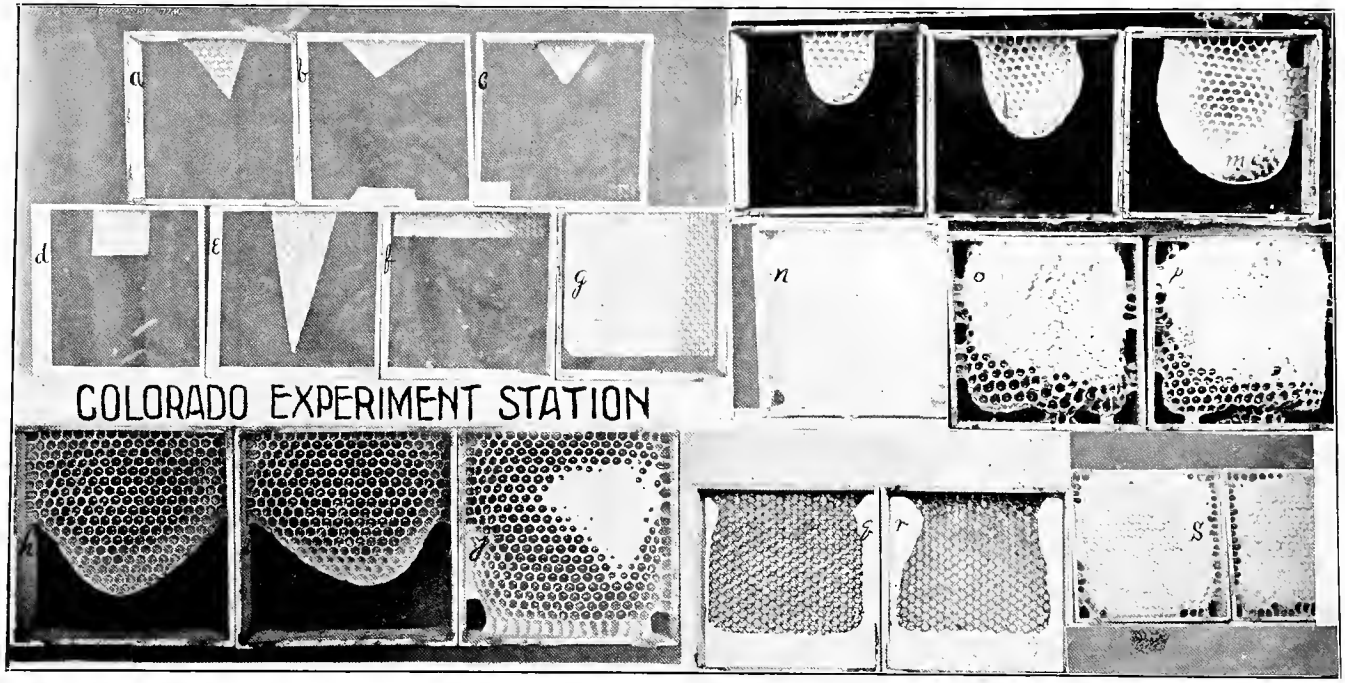

Plate 6.

Table Giving the Proportionate Weights of Honey and Wax in Capped Comb Honey.

KINDS OF COMB.	Thickness in Inches.	Total Weight in Grams.	Weight of the Honey in Grams.	Weight of Wax only in Grams.	Proportion of Wax to Honey.
Natural	1.37	308.45	297.95	10.50	1 to 28.38
"	1.13	174.00	167.71	6 29	1 to 26.66
"	.75	75.00	71.14	3.86	1 to 18.43
On Small Starter	....	374.00	356.76	17.24	1 to 20.70
" " "	....	351.00	334.40	16.60	1 to 20.02
" " "	....	346.00	330.40	15.60	1 to 21.12
" " "	....	344.20	328.50	15.70	1 to 20.92
" " "	....	344.00	328.19	15.81	1 to 20.76
" " "	....	312.80	298.00	14.80	1 to 20.13
" " "	....	287.00	273.20	13.80	1 to 19.80
On Full Piece '99 Deep-Cell Starter	.. .	544 00	525.08	18.92	1 to 27.75
On Full Piece '98 Deep-Cell Starter	....	404.00	384.00	20.00	1 to 19.70

In case of natural comb honey 1.37 inches thick the honey weighed 28.38 times as much as the wax, while the sample .75 of an inch thick, which was built at the same time as the thicker comb and by the side of it, had only 18.43 times as much honey as wax. The intermediate sample (1.13 inches thick) had 26.66 times as much honey as wax.

All other comb samples in this table were taken from sections measuring $4\frac{1}{4}$x$4\frac{1}{4}$ inches and $1\frac{7}{8}$ inches thick. The combs were built on small top starters, except in case of the last two examples, one of which was built upon a full-piece of the "1899" deep-cell foundation and the other upon a similar sheet of "1898" deep-cell foundation. The thickness of the comb was not taken in these sections, but it did not vary much from one and one-fourth inches in any case.

The comb in the sections with small starters did not vary much from one-twentieth of the weight of honey in any case, and the proportion of wax was somewhat greater than in the samples of natural comb of similar thickness.

Passing to the sample of comb on the "1899" deep-cell foundation, we notice, first, that it is much heavier than any of the preceding, and hence much thicker, and in consequence it has a much higher ratio of honey to wax, 1 to 27.75. This is also in keeping with results announced on previous pages, indicating that this

foundation is drawn out by bees into a comb approximating the lightness of the natural product.

In contrast to this last example, but also in harmony with results given on preceding pages, notice that the "1898" deep-cell foundation gave a comb heavier than the preceding, though the honey weighed less by more than one-fourth. The proportion of wax to honey was greater in this case than in any of the others, except that of natural comb only .75 of an inch thick. It should have given a larger proportion of honey than any of the samples built on small starters, as the comb in the latter was thinner in every case.

From the facts given in the above table, it is evident that if we are to secure a comb honey with the least possible amount of wax, it will be necessary to have it built in sections that will secure the greatest thickness of comb. In this way we can also economize very considerably the labor and energy of the bee in wax secretion and comb building.

Attention might also be called to the fact that it takes more wax and more work for the bees to cap ten pounds of honey in thin comb than in thick comb.

The reader will not understand that I am advocating the use of deep sections; there may be other reasons why they are not preferable; I am only mentioning points which, according to my experiments, favor thin sections.

SUBSTITUTES FOR POLLEN.

It is a well known fact among bee-keepers that bees can be stimulated to early brood rearing in spring by putting out some kind of finely ground meal or flour, which they take as a substitute for pollen. Writers vary in their opinions as to what is the best, but it is commonly recommended to use rye, oats, or pea meal. Common wheat flour, wheat middlings, corn meal, barley meal, and malt all have their advocates. It was thought best to put out at one time a good number of these substitutes for the purpose of determining which would be given the preference by the bees. To do this a number of boards were laid flat upon the ground in the vicinity of the apiary, a small pile of each kind of meal put upon them and notes taken upon the results.

It was found that any of the substances used would be taken freely when used alone. Also that the preference did not always go to the same feed.

Results with the first series of tests were published in the Seventh Annual Report of this Station. As that report did not reach a large number of general readers, and as subsequent tests lead to some change in the order of preference, I have thought it best to report upon the work again here. The order of preference as nearly as could be judged ran as follows: Ground whole kernels of oats, corn, and wheat, fine wheat bran,* cleaner dust,† cotton-seed meal, wheat bran, pea meal, wheat flour, rye flour, bean meal, barley meal. The three last named they would hardly touch as long as others were accessible.

As pollen furnishes the bees with nitrogenous food, it seems probable that those substitutes for pollen that have most nitrogen, or rather, that furnish the chemical compounds most nearly in the proportions that they are found in pollen, would be best suited to take the place of pollen in the dietary of the bee.

In order to determine whether or not the chemical composition of the food-stuffs best liked by the bees were more like the composition of pollen than the others, I had a quantity of corn pollen col-

* Bran ground over so as to be fine.

† Waste dust and chaff as taken from cleaners at flouring mill.

lected and taken to Dr. W. P. Headden, Station Chemist, for analysis. In the table below the first analysis is that of corn pollen made by Dr. Headden, and the analyses of the other materials are compiled:

NAME.	Water.	Ash.	Crude Fibre.	Fat.	Protein.	Nitrogen Free Extract.
Corn Pollen	3.444	5.039	7.970	1.526	19.598	62.423
Oats Ground	9.3	3.5	8.5	3.6	11.4	63.7
Corn "	13.6	1.4	1.9	3.4	9.6	70.1
Wheat "	11.5	2.0	2.9	2.0	12.1	69.5
Wheat Bran	11.0	5.7	10.4	5.0	15.9	52.0
Cotton-seed Meal	8.0	6.9	6.7	10.0	42.0	25.7
Pea Meal	8.8	2.6	17.7	1.6	19.2	50.1
Wheat Flour	12.6	0.7	0.7	1.2	11.8	74.1
Rye Flour	14.0	1.6	1.5	1.6	10.5	72.5
Bean Meal	12.0	1.4	2.1	8.5	11.0	65.0
Barley Meal	13.1	2.4	5.7	1.9	11.3	65.6

It will be noticed that, while the nitrogenous material (protein) is high in the pollen, it is not very high in some of the flours best liked by the bees, as for example, corn and oats. Cotton-seed meal runs very high in protein and was not specially liked.

So there are, doubtless, other reasons than the amount of nitrogenous food material, that influence the bees to take substitutes for pollen. It is probable that the aroma and mechanical qualities may have much to do in determining their choice. There is nothing very definite in the above order of choice of the different foods used. The order will often vary on consecutive days, or even on consecutive hours.

It is by no means certain that the flour the bees like best is best for them, for this manner of supplying them nitrogenous food is entirely artificial. The best substitute for pollen is that food which the bees will take and upon which they do best, and it seems probable that it will have a chemical composition approximating that of natural pollen.

SUMMARY OF MORE IMPORTANT CONCLUSIONS.

1. Bees use freely the wax in foundation to extend both the midrib and the cell walls of honey comb.

2. The heavier the foundation used, the heavier, as a rule, will be the comb built upon it.

3. If the midrib of a foundation is much lighter than that of natural comb, the bees are likely to strengthen it by adding wax to the bottom of the cells.*

4. If the midrib of the foundation is thicker than the midrib of natural comb, it will result in a comb with a midrib thicker than the natural. Or, to state it differently, the bees will not thin the midrib of a foundation down to the thickness of worker comb built in the natural way.

5. Midribs of foundation that are not more than .17 of a millimeter (.007 inch) in thickness, are thinned little or none by the bees.

6. Drone comb has a thicker midrib and heavier cell walls than worker comb.

7. A foundation with a heavy midrib and very slight cell walls, will still produce a comb with heavy cell walls.

8. Very high cell walls in foundation are not cut down to the thinness of cell walls in natural comb.

9. The thin and extra thin and the "1899" deep-cell foundations produce a comb that approximates very closely the lightness of that which is naturally made by the bees.

10. When heavy foundations are used, the extra weight of the comb built upon them is due more to the extra weight of the cell walls than to the heavier midrib.

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* Possibly this is only done where there are actual perforations of the comb.

11. When very light foundations are used, the somewhat heavier comb is due almost entirely to the midrib being heavier than that of natural comb.

12. When foundations containing an abundance of wax to build the entire comb are used, the bees still add much more wax, sometimes nearly enough to build the comb without the help of the wax in the foundation.

13. Wax seems to be given with the best economy when the midrib of the foundation is of the thickness of the midrib of natural comb, and when there is a small, or at most a moderate, amount of wax in the cell walls.

14. Poorly attached combs in sections seem to be more the result of weak colonies and poor honey flow than to the kind of starter that is used; though large starters and strips of foundation in the bottom of the sections do help to strengthen the union of comb to the section.

15. Separators between the sections are essential to the best results in producing comb honey.

16. The thicker the comb, whether natural or artificial, the greater the proportion of honey to wax in it.

17. In natural worker comb, one inch thick, the proportion of wax to honey is between 1 to 20 and 1 to 25 by weight.

EXPLANATION OF PLATES.

PLATE 1.

a, blackened super foundation; *b*, sections of comb built on a strip of blackened foundation as shown at *a*; *c*, comb built on narrow strip of foundation as shown at *a*; *d*, fully drawn comb built on full-piece starter of black foundation; *e*, midrib of natural worker comb after removing the cells; *f*, midrib of comb built on "1898" deep cell foundation; *g*, comb that the bees have just begun to draw on medium brood foundation, enlarged about two diameters; *h*, like the preceding except that the cells are fully drawn.

PLATE 2.

a, cross-section of very heavy foundation; *b*, midrib of comb built on very heavy foundation in upper two-thirds, the lower third being natural midrib extended by the bees; *c*, cross-section of medium brood foundation; *d*, like the preceding except that the bees had begun to draw out the cells in the upper two-thirds of the figure; *e*, the same as *d* with the cells farther drawn; *f*, a rather heavy super foundation blackened with lamp-black; *g*, section of comb on heavy foundation shown at *a*; *h*, comb on foundation shown at *f*; *i*, the upper two-fifths like *h* and the remainder natural drone comb; *j*, section of thin super foundation; *k*, the same as the preceding with the cells partly drawn; *l*, section of extra thin foundation.

PLATE 3.

a, section of comb on thin foundation in upper half, natural comb in lower half; *b*, natural comb; *c*, natural comb cut from side to side of a section of honey; *d*, comb built on "1898" deep-cell foundation; *e*, cells of natural worker comb cut in cross-section; *f*, cells of natural drone comb in cross-section; *g*, cells of worker comb in cross-section, the upper one-third of which was built on the foundation shown at *f* of Plate 2, and the rest is natural.

PLATE 4.

a, cross-section of comb cells, the upper third of which were built on "1898" deep-cell foundation; *b*, cross-section of worker

comb built on very heavy foundation; *c*, section of comb built on "1898" deep-cell foundation; *d*, section of "1898" deep-cell foundation; *e*, cross-section of the cells of "1898" deep-cell foundation before being worked by the bees; *f*, section of comb on the "1898" deep-cell foundation; *g*, section of "1899" deep-cell foundation; *h*, partly drawn comb on the preceding foundation.

PLATE 5.

a, section of comb on "1899" deep-cell foundation; *b*, cross-section of cell walls of the "1899" deep-cell foundation before they have been worked at all by the bees; *c*, section of the Weed "thin-base-and-heavy-wall" foundation; *d*, section through comb to show that the midrib can be cut so as to give a straight line; *e*, another sample of comb manufactured by Mr. Weed with extremely thin midrib and high and heavy walls; *f*, comb on medium brood foundation; *g*, comb on extra thin super foundation; *h*, sections of honey showing how comb is bulged when separators are not used; *i*, comb on "1898" deep-cell foundation somewhat magnified, showing the heavy basal portion of the cell walls.

PLATE 6.

a to *g*, different methods of using starters in sections; *h*, *i* and *j*, showing how comb is built on starters that fill the sections half way down; *k*, *l* and *m*, showing method of building down comb from small starter; *n*, comb built on a full-piece starter; *o* and *p*, the way sections are finished in weak colonies or during a poor honey flow, particularly with small-piece starters; *q* and *r*, large piece starters that the bees have gnawed away during dearth of honey; *s*, the way sections should be finished.

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Apiary experiments.Foundation in comb bu

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